

## Metal-rich debris discs around white dwarfs

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**Abstract.** We have identified two moderately hot ( $\sim 18000$ – $22000$  K) white dwarfs, SDSS J1228+1040 and SDSS J1043+0855, which exhibit double-peaked emission lines in the Ca II  $\lambda\lambda 8600$  triplet. These line profiles are unambiguous signatures of gaseous discs with outer radii of  $\sim 1R_{\odot}$  orbiting the two white dwarfs. Both stars accrete from the circumstellar material, resulting in large photospheric Mg abundances. The absence of hydrogen emission from the discs, and helium absorption in the white dwarf photospheres demonstrates that the circumstellar material is depleted in volatile elements, and the most likely origin of these gaseous rings are tidally disrupted rocky asteroids. The relatively high mass of SDSS J1228+1040 implies that planetary systems can not only form around  $4 - 5 M_{\odot}$  stars, but may also survive their post main-sequence evolution.

### 1. Introduction

While more than 250 extra-solar planets orbiting main-sequence stars have been discovered, the destiny of planetary systems in the late stages of the evolution of their host stars is very uncertain, and so far no planet has been found around a white dwarf. Infrared excess detected around a number of white dwarfs has been interpreted as the signature of dust discs (e.g. Zuckerman & Becklin 1987; Becklin et al. 2005; Kilic et al. 2006; von Hippel et al. 2007). The photospheres of these white dwarfs are rich in metals (Zuckerman et al. 2007), indicating ongoing accretion from the circumstellar material. The likely origin of these debris discs are tidally disrupted asteroids (Jura 2003), and hence they represent a close association with the planetary systems that the white dwarf progenitor stars may have had. However, while the infrared excess detected around these white dwarfs can be explained in terms of a dusty debris disc, the observations actually do not provide any strong constraint on the geometry of the source of the infrared light (e.g. Reach et al. 2005). We summarise here our recent discovery of two white dwarfs in the SDSS spectroscopic data base which exhibit double-peaked emission lines of Ca II  $\lambda\lambda 8600$ , unambiguously confirming a circumstellar disc-like structure (Gänsicke et al. 2006, 2007)

### 2. Why discs? Why metal-rich? Why planetary debris?

Visually inspecting the SDSS spectra of several hundred white dwarfs, we noticed very unusual Ca II  $\lambda\lambda 8600$  emission lines in SDSS J122859.93+104032.9 (Fig. 1) and SDSS J104341.53+085558.2 (Fig. 2). The double-peaked shape of these line profiles is the unmistakable signature of gas rotating around these stars on Keplerian orbits (Horne & Marsh 1986; Littlefair et al. 2006).

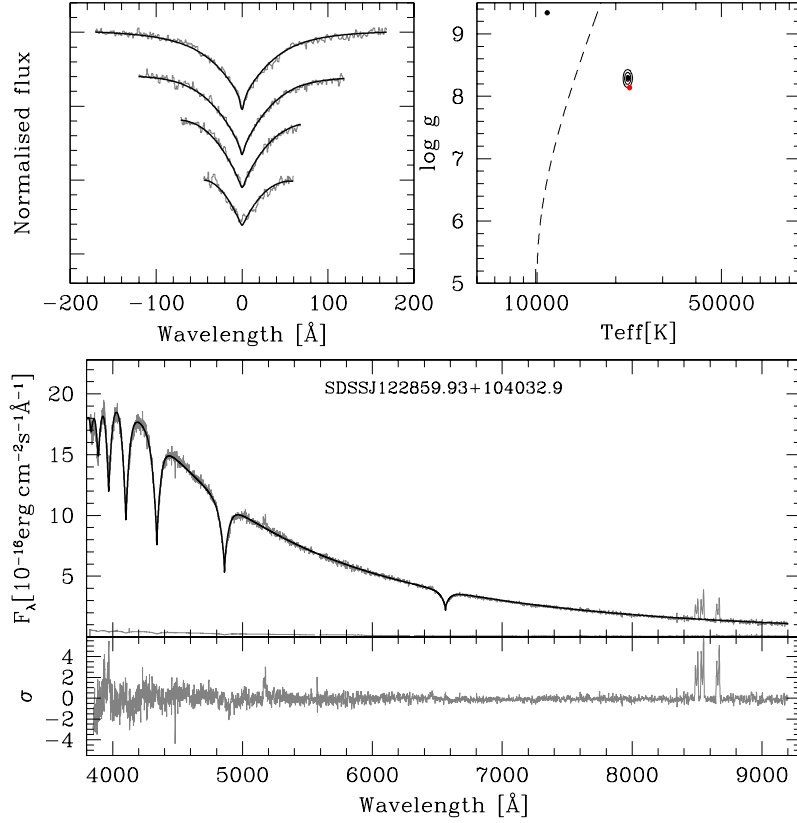


Figure 1. The Sloan spectrum of SDSS J1228+1040 along with white dwarf model fits. Top left: normalised H $\beta$  to H $\epsilon$  line profiles (top to bottom, gray lines) along with the best-fit white dwarf model (black lines). Top right panel: 1, 2, and 3 $\sigma$   $\chi^2$  contour plots in the  $T_{\text{eff}} - \log g$  plane. The line profiles allow a “hot” and a “cold” solution (black dots) on either side of the temperature corresponding to maximum Balmer line equivalent widths (dashed line). The degeneracy in the line profile fits is lifted by the best-fit to the continuum slope (red dot). The best-fit to the line profiles results in  $T_{\text{eff}} = 22\,292 \pm 296$  K and  $\log g = 8.29 \pm 0.05$ . Bottom panels: the white dwarf spectrum and associated flux errors (gray lines) along with the best-fit white dwarf model (black line) to the 3850–7150 Å wavelength range (top) and the residuals of the fit (gray line, bottom). Note the strong, double-peaked emission lines of Ca II  $\lambda\lambda$  8600.

While Ca II emission lines are observed in a few white dwarfs with low-mass companions (e.g. Marsh & Duck 1996), these lines are *always* accompanied by Balmer emission. In fact, even WD 0137–349 and SDSS 1035+0551, two white dwarf/brown dwarf binaries, display copious amounts of H $\alpha$  emission (Maxted et al. 2006; Littlefair et al. 2006). In contrast to those binaries, the spectrum of SDSS J1228+1040 is totally devoid of Balmer emission. We obtained time-resolved intermediate resolution spectroscopy and photometric time series of SDSS J1228+1040, which clearly rule out the possibility of this object being a white dwarf plus low mass companion binary. Photospheric Mg I  $\lambda$  4482 absorption lines demonstrates that both SDSS J1228+1040 and SDSS J1043+0855

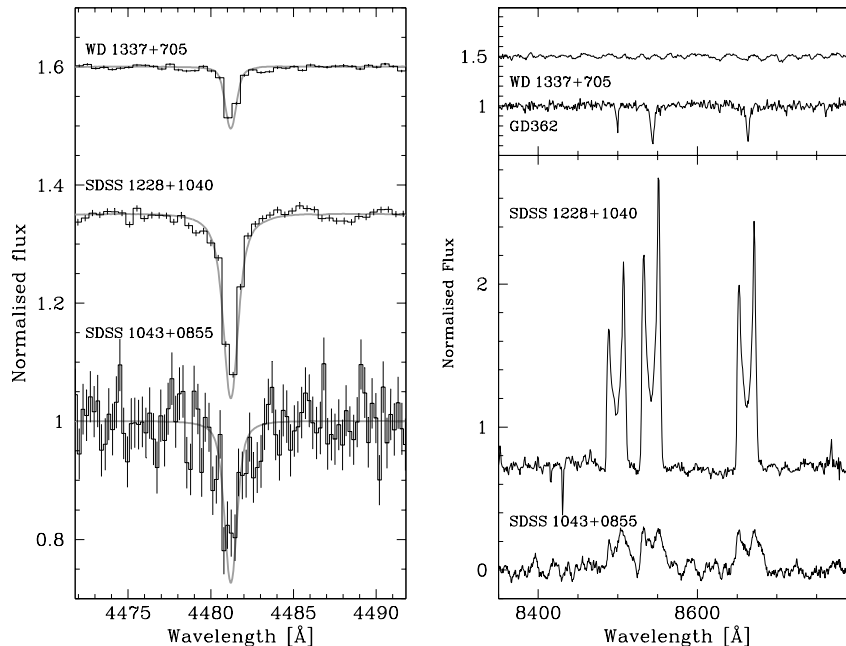


Figure 2. Left panel: The Mg I absorption lines in the moderately hot three DAZ white dwarfs WD 1337+705, SDSS J1228+1040, and SDSS J1043+0855. Best-fit models that were used to determine the abundances are shown as gray lines. Right panels: The spectra of these three DAZ plus that of the cold DAZ GD 362 centred on the Ca II  $\lambda\lambda 8600$  triplet. The spectra of SDSS J1228+1040 and SDSS J1043+0855 display double-peaked Ca II emission lines originating in debris discs with outer radii of about  $1R_{\odot}$ . In GD 362 photospheric Ca II absorption lines are observed, and no Ca II features are present in the spectrum of WD 1337+705. The comparison of these four objects suggests that Ca II emission can occur only around white dwarfs which are sufficiently hot to ionise/excite Ca in the circumstellar debris disc, and that the equivalent width of the Ca II emission may be correlated with the accretion-induced photospheric metal abundance.

are accreting from their circumstellar discs. Stellar parameter of the two white dwarfs (Fig. 1 & 2, Table 1) were determined from spectral fits using TLUSTY and SYNSPEC models (Hubeny & Lanz 1995). The absence of hydrogen (and/or helium) emission from material close to a  $\sim 20\,000$  K white dwarf implies that the circumstellar material must be depleted in volatile elements. A low content ( $\lesssim 10\%$  solar) of helium in the circumstellar material is corroborated by the absence of helium lines in the spectrum of SDSS J1228+1040. A dynamical model of the Ca II line profiles in SDSS J1228+1040 computed following Horne & Marsh (1986) implies an outer radius of the disc of just 1.2 solar radii. This circumstellar material can not have survived the red giant phase of the white dwarf progenitor at its current location, and must have been supplied from distances greater than  $1000 R_{\odot}$  after the formation of the white dwarf. A plausible origin is the tidal disruption of a rocky asteroid (Jura 2003), probably destabilised from its original much wider orbit by interaction with a larger object (Debes & Sigurdsson 2002).

Table 1. Stellar parameters of SDSS J1228+1040 and SDSS J1043+0855.

System	$T_{\text{eff}}$ [K]	$M_{\text{WD}}$ [ $M_{\odot}$ ]	$\tau_{\text{cool}}$ [yr]	$M_{\text{MS-prog.}}$ [ $M_{\odot}$ ]	Mg abund. [ $\odot$ ]	Ca II E.W. [Å]
SDSS J1228+1040	22292	0.81	$1.0 \times 10^8$ yr	$\sim 4$	0.7	61.1
SDSS J1043+0855	18330	0.67	$1.8 \times 10^8$ yr	$\sim 2.7$	0.3	21.2

### 3. Implications and conclusions

It has been suggested that planetary systems may survive the post-main sequence evolution of their host stars (Burleigh et al. 2002; Villaver & Livio 2007), however, no planet has yet been discovered around a white dwarf. The detection of debris discs from rocky asteroids around white dwarfs, such as SDSS J1228+1040 and SDSS J1043+0855 and the cooler white dwarfs with dusty debris discs lends strong support to the survival hypothesis. It appears also entirely possible that these white dwarfs may still have planetesimal objects or planets. SDSS J1228+1040 is particularly interesting, as its relatively high mass implies that its progenitor must have had a mass of  $\sim 4 M_{\odot}$  (Dobbie et al. 2006), suggesting that also short-lived massive stars may be host to planetary discs. This is in accordance with the detection of a relatively massive debris disc around the young A2e star MWC 480 (Mannings et al. 1997).

### References

- Becklin E. E., Farihi J., Jura M., Song I., Weinberger A. J., Zuckerman B., 2005, *ApJ Lett.* 632, L119
- Burleigh M. R., Clarke F. J., Hodgkin S. T., 2002, *MNRAS* 331, L41
- Debes J. H., Sigurdsson S., 2002, *ApJ* 572, 556
- Dobbie P. D., Napiwotzki R., Burleigh M. R., Barstow M. A., Boyce D. D., Casewell S. L., Jameson R. F., Hubeny I., Fontaine G., 2006, *MNRAS* 369, 383
- Gänsicke B. T., Marsh T. R., Southworth J., 2007, *MNRAS* 380, L35
- Gänsicke B. T., Marsh T. R., Southworth J., Rebassa-Mansergas A., 2006, *Science* 314, 1908
- Horne K., Marsh T. R., 1986, *MNRAS* 218, 761
- Hubeny I., Lanz T., 1995, *ApJ* 439, 875
- Jura M., 2003, *ApJ Lett.* 584, L91
- Kilic M., von Hippel T., Leggett S. K., Winget D. E., 2006, *ApJ* 646, 474
- Littlefair S. P., Dhillon V. S., Marsh T. R., Gänsicke B. T., Southworth J., Watson C. A., 2006, *Science* 314, 1578
- Mannings V., Koerner D. W., Sargent A. I., 1997, *Nat* 388, 555
- Marsh T. R., Duck S. R., 1996, *MNRAS* 278, 565
- Maxted P. F. L., Napiwotzki R., Dobbie P. D., Burleigh M. R., 2006, *Nat* 442, 543
- Reach W. T., Kuchner M. J., von Hippel T., Burrows A., Mullally F., Kilic M., Winget D. E., 2005, *ApJ Lett.* 635, L161
- Villaver E., Livio M., 2007, *ApJ* 661, 1192
- von Hippel T., Kuchner M. J., Kilic M., Mullally F., Reach W. T., 2007, *ApJ* 662, 544
- Zuckerman B., Becklin E. E., 1987, *Nat* 330, 138
- Zuckerman B., Koester D., Melis C., Hansen B., Jura M., 2007, *ApJ* in press, arXiv:0708.0198